U. S. Department of Agriculture Rural Electrification Administration

INFORMATION AND EQUIPMENT FOR ELECTRICAL HAY AND GRAIN DRIER INSTALLATION

FARM STORAGE PROBLEMS

By D. W. Teare July 1, 1952

Crop production in the United States has reached an all-time peak. In spite of the fact that great progress has been made in increasing annual yields, the farm methods for preventing waste and loss of this production during harvest and storage have not kept pace. Storage and processing losses of crops held on the farm have also reached an all-time peak. It is reported that twenty-five percent of the feed value of hay is lost every year by antiquated methods of curing and harvesting. This does not take into account complete losses of hay due to severe weather conditions and spontaneous combustion. It is also reported that in 1948 farmers lost more grain during storage on their farms than was shipped to Europe under the Marshall Plan that year. Much of this loss was due to heating, molding, and insect damage, because of storage at too high a moisture content.

The present method of curing hay is approximately the same method that our ancestors used to provide feed for their livestock during the winter months. Curing methods developed centuries ago are still in use on most of the farms in the United States. The most common method is to cut the hay when the weather seems to be favorable. It then lies on the ground from three to seven days or more, until dry. It is then raked and stored in barns or in stacks, as loose chopped or baled hay. There has been considerable progress in the development of field equipment for cutting, gathering, and storing cured hay. But ninety-nine percent, or more, of the farmers still depend on good weather, a bright sun, and their ability as weather prophets to get their hay crop safely cured, just as their great-great grandparents did.

The chief problem faced by every farmer at haying time is sufficient curing of the hay to prevent spontaneous combustion. Every farmer is torn between two fears in determining when his hay should be gathered. First, he is afraid the hay may not have dried sufficiently. More than twenty to twenty-five percent moisture in the hay will cause it to heat, which may set his barn on fire and perhaps burn up all of his property. The farm fire loss is $100,000,000 yearly, of which five percent is estimated to be due to spontaneous combustion. The other fear is that if he does not gather the hay soon enough loss of feed value will result because of leaf-shattering or over-drying.

Obviously, the first fear is the governing factor and most of the roughage gathered for feeding on the farm in the United States is left in the field to dry until it is of medium or low quality. Because of its scarcity, high quality hay brings a premium price. Many farmers sell their best hay, keeping the inferior grades for home use. Poor quality feed reduces animal growth and milk production unless expensive concentrates are used to overcome the hay deficiencies.

Grain harvesting by old methods prevented most of the problems that are faced today. Before the combine and corn picker were developed it was customary to let the grain stand in the field until it ripened and dried well. It was then bound into bundles and shocked or stacked for a period of time before it was threshed or the ear corn shelled. During this period the grain was said to go into the "sweat"; that is, the moisture content was reduced by evaporation. Thus when the grain was threshed it had low enough moisture content to store indefinitely

without heating, molding, and in most cases, without excessive insect damage.

New methods and machinery have caused problems to develop that rarely had to be met in the past. Grain is now cut and threshed or picked in one operation. It is then marketed or stored immediately. Since the machines have been constructed to harvest the grain successfully at high moisture contents farmers have a tendency to gather the grain before it is ready to store. This results in excessive spoilage or a reduction in price at the grain elevator because of the high moisture content. Much grain stored on the farm has too much moisture to be eligible for Government loans. Such grain has to be marketed immediately or losses are very heavy. Recently the Food and Drug Administration sponsored legislation which will prevent the elevators and mills from buying and using grain with excess moisture and showing excessive damage from heat or weavil infestation for human consumption.

Favorable grain harvesting periods are frequently very short. This is due to the fact that rain, hail, or wind frequently shatter the grain or cause it to lodge in such a way that much of it is lost in the harvesting operation. Because of this danger farmers will always have a tendency to cut the grain before it is dry enough to store safely. Artificial drying is essential to cure the grain and prevent excessive losses.

Another problem is the change in moisture content of standing grain throughout the twenty-four hour day. In the late afternoon, at night, and in the early morning the grain tends to absorb moisture, increasing its moisture content which reduces its keeping qualities. During the middle of the day, from 10:00 A.M. until 4:00 P.M., the standing grain generally has its lowest moisture content. Consequently, many farmers delay starting their harvesting in the morning until 9:00 or 10:00 and stop at 4:00 or 5:00 in the afternoon. However, those farmers who have very large grain acreages frequently start their combines very early in the morning and run them until dark, taking the chance that the loss from high moisture content will not be excessive. Most farmers will harvest from daylight until dark when bad weather threatens. These practices have definitely resulted in increased storage losses and lower prices at the elevator. Practically all of this loss can be stopped by the use of electric power to dry grain. When grain can be dried artificially, it is possible to complete harvest from one to three weeks earlier than customary.

Within the past fifteen years a great deal of research has developed and is still being done on the methods of reducing the moisture content of both hay and grain after storage. The purpose of these studies is to discover practical methods for reducing the moisture content of stored products, to stop spoilage, reduce losses, and improve the quality of products that can be harvested before drying is completed in the field. In many cases there are opportunities to use electric power to reduce loss and improve quality of farm products.

The first work done on this subject was by the TVA. The work was started as a result of the unfavorable climatic conditions in the TVA area for the customary hay curing methods. Low quality roughages in that area are due to frequent summer rains, high humidity, and cloudy weather. It was discovered that hay partially cured in the field could be completely dried in the barn. This study in crop drying came about as the result of TVA efforts to increase the growing of tame grasses and legumes for the feeding of livestock and the development of a more diversified agriculture. The chief problem was in the curing of legume hays.

Legume hays include alfalfa, lespedeza, soybeans, red clover, field peas, the vetches, and numerous other varieties which are processed for hay. In general, these plants may be characterized as having a high leaf content; that is, a large percentage of the total weight of the dried plant is leaves. The leaves in legume plants contain from two to three times as much protein, fats, carbohydrates, vitamins, minerals, and other plant nutrients as are contained in the stems. For this reason, the loss of the leaves is especially serious. Leaves are lost by shattering whenever excessive sun drying occurs or when it is necessary to turn the hay several times in curing it, because of wet weather. Few stems are ever lost; therefore, the loss in weight and food value that occurs in legume hays of good color is almost entirely from leaf loss.

Alfalfa hay that has lost all of its leaf content would have one-quarter to one-fifth of the feed value that it had when it stood in the field. It is highly important that the hay making and gathering process be designed to conserve the leaves, stop fading, and prevent rain damage. Leaves shatter when the moisture content falls below thirty-five to forty percent. As the hay gets drier, more leaves shatter during gathering and storage. Many different methods have been tried but the only successful method is to gather the hay when there is just enough moisture content in the plant to prevent the leaves from shattering. This can generally be done within four to six hours after cutting. This requires artificial drying after the hay is stored but it does eliminate practically all weather hazards and other losses, including fire.

Legume hays also contain vitamins. Color is an indication of the vitamin content. This is particularly true of vitamin A which is formed in the chlorophyll of the plant. The chlorophyll contains carotene which in turn is the carrier of vitamin A. Vitamin A is lost when the plant fades due to excessive sunlight, by repeated wetting and drying, by storage at too high a moisture content, or from oxidation during storage periods. All plants contain enzymes which are chemical agents that cause destruction of the plant cells and the vitamin content. Rapid and sufficient drying of the hay deactivates those enzymes, thus maintaining the color and vitamin content and the food value of the plant. Vitamin D is placed in the plant by sunlight both before and after cutting. The hay that remains in the field for several days would have more vitamin D than hay that is cut, raked, and stored on the same day. The loss of vitamin D because of quick removal of the hay from the field is not serious since there are generally other farm sources of vitamin D which are available to the animals, or their feed may be supplemented by fish meal or oil.

Crop Drying Fundamentals

The moisture content of growing plants which are cut for hay ranges from 65 percent to 95 percent. This moisture content depends on the time of year, the age of the plant, the kind of plant, and rain-fall or irrigation during the growing period immediately before cutting the crop. This means that the dry matter in the growing plant is equivalent to from one-twentieth to one-third of the total weight of the plant. The moisture content of hay is generally stated on the "wet" basis. This means that the moisture content is based on the entire weight of the plant or hay, including the moisture, at the time of the moisture determination test. Dry basis of calculating moisture content is generally used in laboratory methods or in calculating feed rations. Since the farm custom is to buy or sell hay or grain by gross weight, the moisture content is always calculated on the "wet" basis.

In drying hay for safe storage the maximum moisture content is generally considered to be 20 percent. When more than 20 percent moisture is present there is danger of the product's heating, which may result in spontaneous combustion and great fire loss. Even when heating does not result in fire there is a large loss of food value from oxidation. However, considerable enzmic reaction may take place with a 20 percent moisture content. Moisture content less than 15 percent is very desirable for both grain and hay, but it is not desireable to reduce moisture contents below 10 percent. Hay having less than 10 percent moisture is very brittle and the leaves shatter very badly when the hay is moved from the barn or stack to the feed bunks. There is also some tendency for animals to injure their mouths with very dry hay. <u>For most practical purposes artificially cured hay should have a moisture content ranging between 12 percent and 15 percent for safety and satisfactory feeding.</u>

Extremely low moisture content may also reduce the farmer's return because it will reduce the gross weight of the hay he has to sell. It is a good plan to sell artificially cured hay on the basis of percentage of dry matter in the ton of hay or on the basis of digestible nutrients, including vitamin content. This requires a chemical analysis but it protects both buyer and seller.

In good weather the sun is very efficient in removing moisture from hay in the fields. The trouble is that farmers are seldom able to select weather of sufficient duration that the sun can shine on the hay long enough to <u>cure it properly</u>. On the other hand, if the weather is good a hot sun may over-dry the hay, causing color fading and leaf shattering when the hay is gathered. Even with long-range weather forecasting it is impossible for a farmer to consistently pick weather which will guarantee him a high quality hay crop. Therefore, the plan has developed for artificial drying of hay which calls for cutting, raking, and storing in one day's time. Then air is blown through the hay until the excess moisture is removed sufficiently for safe storage.

As an example of the efficiency of the sun in removing moisture, assume that a given sample of hay contained 85 percent moisture when it was cut. In 4 to 6 hours the sun, on a bright, hot day, would remove sufficient water to reduce the moisture content of the hay to 40 percent. A ton of hay containing 40 percent moisture would then have 1,200 pounds of dry matter and 800 pounds of water. In order to find the effectiveness of the sun it is necessary to calculate the total

weight of the 1,200 pounds of dry matter and moisture before the sun started drying the hay. Since 85 percent of the freshly cut hay was moisture, then 15 percent was dry matter. Therefore, since we have 1,200 pounds of dry matter, the weight of the green hay that supplied this 1,200 pounds of dry matter totalled 8,000 pounds. In other words, the sun removed 6,000 pounds of water to change 85 percent moisture content hay to one ton of 40 percent moisture content hay.

If we then put this hay in the barn and dry it to a moisture content of 15 percent, it will then contain only 211 pounds of moisture and have a storage weight of 1,411 pounds. Thus the air blown by the fan used in the hay drier would have to remove 589 pounds of water to make the ton of hay at 40 percent moisture safe for storage. After completion of drying the one ton of 40 percent moisture hay would weigh only 1,411 pounds.

Perhaps if the problem were stated differently it could more readily be seen that the amount of moisture to be removed by the fan is generally about 10 percent of the total moisture removed from the hay. If the moisture content of the barn-dried hay is 12 percent then one ton of hay would contain 240 pounds of moisture and 1,760 pounds of dry matter. The 1,760 pounds of dry matter was originally only 15 percent of the green hay having 85 percent moisture. Then $\frac{1,760}{.15} = 11,733$ pounds which is the original weight of the freshly cut hay before drying began. This means that a total of 11,733 - 2,000, or 9,733 pounds of moisture had to be removed from the hay to reduce it to one ton of hay at 12 percent moisture content. If the moisture content of the hay was reduced to 40 percent in the field, then the sun would remove 8,800 pounds of the water. That is, 100 - 40 = 60percent of the weight of 40 percent moisture hay is dry matter and $\frac{1,760}{.60} = 2,933$ pounds is the total weight of hay and moisture at 40 percent moisture content. The 11,733 - 2,933 = 8,800 pounds of moisture removed by the sun. Two thousand, nine hundred thirty-three pounds of hay with 40 percent moisture would then be gathered from the field and dried to one ton of weight in the barn. This would require the removal of 933 pounds of water which is equivalent to 9.4 percent of the original mositure which had to be removed by the fan.

As a general rule we can say that less than 5 percent of the original moisture in the freshly cut green plant remains in dried hay that can be safely stored. In the above case, 240 pounds of moisture that remains in the dry hay at 12 percent moisture content is equivalent to only 2.4 percent of the original moisture in the hay when it was cut. The sun was made to remove 88.2 percent of the water from the hay while it remained in the swath for a period of 4 to 6 hours. The fan removed 9.4 percent of the original moisture during the barn-curing period.

The above calculations show the quantity of moisture removed but they do not indicate the effect of temperature and humidity on the rate of drying or the time required to dry the hay completely after it is stored in the barn. This time depends on the air temperature, relative humidity, and the quantity of air blown. Air at less than 60 degrees Fahrenheit does not remove the moisture from the hay in any appreciable quantity. This is due to the limited ability of cool air to absorb moisture. As the air temperature rises, its ability to absorb moisture greatly increases. Consequently, the relation of air temperature and its moisture content at any time in the drying period is of considerable importance. This is known as the relative humidity of the air.

If the relative humidity is low, even though air temperature approaches 60 degrees, there will be some evaporation of moisture from the hay. If the relative humidity is high there will be little drying of hay even though the air is quite warm. One hundred percent saturation of the air is considered to occur during rainfall, during heavy fogs, or when ground mists in river bottoms or at night are heavy. Air blown into the hay under such conditions will add moisture to the hay rather than remove it. If the fan is not shut off during periods of high relative humidity, the hay tends to mold badly, fading occurs, oxidation and enzymes become more active. Heating does not occur because the exchange of air removes any heat that might develop from increased oxidation.

All these conditions tend to lower the quality of the hay and reduce its feeding value. Therefore, there is little point in operating the blower fan to dry hay or grain unless the relative humidity is low enough to cause the air to absorb water from the hay or grain. The only exception to this rule is when poor drying conditions exist for a long period of time. Under such circumstances the blower fan should be operated one hour out of every four hours to remove any heat that may form in the hay or grain.

Small grain rarely has more than 20% moisture but ear corn may have as much as 30%, even 35% moisture in very soft corn. The removal of excess moisture from small grain is more difficult than drying ear corn or hay.

In most cases air can not be forced through more than eight feet of small grain with the fans and motor sizes available on the farm. The moisture to be removed from grain can be calculated by knowing the desired moisture content and the moisture content of the damp grain.

Assume that 500 bushesl of wheat are to be dried from 18% moisture to 13% moisture content. A standard bushel of #1 wheat is considered to weigh 60 pounds at 15.5% moisture. Therefore, there are 50.7 pounds of dry matter in the standard bushel of wheat. If the undreid wheat has 18% moisture, the dry matter is 82% of the damp wheat 100-18 = 82.

In 800 bushels of wheat there would be 500 X 50.7 = 2$,350 pounds of dry matter.

There fore $\frac{25,350}{.82}$ = 30,914 pounds total weight of 500 bushels of 18% moist wheat.

The 500 bushels of wheat dried to 13% moisture would weigh $\frac{25,380}{.87}$ = 29,138 pounds total weight at 13% moisture.

Then 30,914 - 29,138 = 1,776 pounds of water must be removed by the fan.

A bushel ear corn at 15.5% moisture weights 72 pounds. Therefore 72 X 15.5 = 11.16 pounds of moisture in a bushel of 15.5% moist ear corn. 72 - 11.16 = 60.84 pounds of dry matter in one bushel of ear corn at 15.5% moisture.

At 30% moisture the 60.84 pounds of dry matter would weigh $\frac{60.84}{70}$ = 86.91 pounds. The excess moisture above 15.5% must be removed. This is equal to 86.91 - 72 = 14.91 pounds per bushel. If a 1,000 bushels are to be dried 1,000 X 14.91 = 14,910 pounds of moisture must be removed.

RELATIVE MILK PRODUCTION PER ACRE OF FORAGE
(INCLUDING OTHER FEEDS) BELTSVILLE, 1947

Forage	Alfalfa dry matter		Relative Milk Production
	Preserved	Consumed per 100 pounds of milk produced	
	Percent	Pounds	Percent
Barn-cured hay	151.5	41.4	148.2
Silage	142.7	41.2	140.3
Field-cured hay	100.0	40.5	100.0
*Dehydrated hay	159.9	43.3	149.6

*Note: Few farmers have need for a dehydrator on their farms and capital investment is prohibitive except on commercial installations.

Taken from page 10, Relative Efficiency of Four Methods of Harvesting and Preserving Forage Crops for Dairy Feed.

DRY MATTER AND MOISTURE WEIGHT PER TON FOR VARIOUS MOISTURE CONTENTS IN HAY

	At 85% Pounds	At 60% Pounds	At 40% Pounds	At 30% Pounds	At 20% Pounds	*At 10% Pounds
Wt. Moisture per Field ton	1,700	1,200	800	600	400	*200
Wt. DryMatter per Field ton	300	800	1,200	1,400	1,600	*1,800
Wt. Moisture to be removed to produce 10% Hay	1,667	1,112	667	445	223	None
Wt. Green Hay to make 1 Ton 10% Cured Hay	12,000	4,500	3,000	2,577	2,111	*2,000
Wt. of Moisture to be Removed	10,000	2,500	1,000	577	111	None

* Very difficult to obtain low moisture content in field of cured hay.

POUNDS WATER PER TON OF HAY REMOVED BY THE SUN AND BY THE DRIER IN MAKING A TON OF 10% MOIST ALFALFA HAY AT VARIOUS MOISTURE CONTENTS

Hay	% Moisture in Plant When Gathered	Pounds water Removed by the Sun	Pounds Water Removed by the Drier to make 10% Hay
Green Hay	85%	None	10,000 lbs.
Partly Cured Hay	60%	7,500 lbs.	2,500 lbs.
Partly Cured Hay	50%	8,400 lbs.	1,600 lbs.
Partly Cured Hay	40%	9,000 lbs.	1,000 lbs.
Partly Cured Hay	*30%	9,429 lbs.	571 lbs.
Partly Cured Hay	*20%	9,750 lbs.	250 lbs.
Well Cured Hay	*10%	*10,000 lbs.	None

*NOTE: Very difficult to make 10% hay of good quality by sun curing only. Leaf shattering occurs during hay gathering when moisture content is less than 35%.